ORIGINAL ARTICLE

Validation of Ottawa ankle rule utilizing radionuclide skeletal scintigraphy

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Abstract

Aims Ankle and foot injuries, especially among teenagers and young adults, are frequently encountered by the primary care physicians. Most common ankle injuries are sprains due to inversion injuries to the lateral ankle ligaments. It has been observed that the overall number of ankle radiographs in the ER is around 15-20%, which includes about 30-40% unnecessary radiographs. Ottawa Ankle Rule (OAR) was first established in 1992, to reduce that unnecessary load on x-ray departments. In light of the current universal practice of evidence-based medicine it is important to undertake verification of the subjective OAR. Bone scintigraphy by merit of its high sensitivity was chosen as the imaging modality of choice to validate the accuracy of OAR.

Methods The study population comprised of 50 OAR-positive cases and 10 normal controls. Each case was scanned using 3-phase bone scintigraphy (TPBS), following a preliminary radiograph.

Results Out of 50 OAR-positive cases, x-rays showed frank fractures in only 12 cases, whereas bone scan was positive in 45 cases, out of which 43 had active bone lesions, the remaining 2 had a soft-tissue injury. By considering the TPBS bone scan as the gold standard, we found the sensitivity of OAR was 95% and specificity 61.5% with PPV and NPV at 90% and 80% respectively.

Conclusion We conclude that there is a high concordance between the OAR and the bone scan and that the OAR is evidence-based as determined by the successful verification of the OAR by the TPBS in 95% of the cases. Based on our findings we recommend the routine practice of the OAR in all emergency departments. In patients with acute ankle/foot injuries, with a positive OAR, even with a negative x-ray, the injury should not be taken lightly and if required, a bone scan should be performed for confirmation of lesion. Bone scintigraphy rather than plain radiography appears to be the modality of choice in this situation being cost- and time-effective without compromising the quality of medical care.

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Key words*: Ottawa ankle rule, radionuclide bone scan, x-ray, radiograph*

Introduction

Ankle and foot injuries, especially among teenagers and young adults, are commonly encountered by the primary care physicians. The commonest ankle injuries are sprains due to inversion injuries to the lateral ankle ligaments [1]. It has been observed that the overall number of ankle radiographs in the emergency room (ER) is around 15-20% [2], which includes about 30-40% unnecessary radiographs [3].

Although at first glance, ankle injuries may appear to be minor, up to 44% of patients may have persistent symptoms one year after the injury. Though only a few of these cases suffer a fracture, nearly all are investigated through plain x-rays of the ankle or foot, or both [4]. To deal with this clinical problem, a set of guidelines known as the Ottawa ankle rules, were first developed at the University of Ottawa in Canada in 1992 [5], stating that ankle x-rays are only required if there is any pain or tenderness at posterior edge or tip of either of the malleoli, and foot x-rays are only required if there is any pain or tenderness at the base of 5th metatarsal *or* the navicular bone *or* the patient is unable to bear weight both immediately post injury and in the emergency department.

Stiell *et al.* in 1994 [6] showed that by proper implementation of this rule there was a reduction in ankle radiography by 28%. Pigman *et al.* [7] also studied acute ankle injuries in emergency departments of three hospitals during the pre-intervention and intervention periods and observed significant reduction in radiographic requests.

The impact of the Ottawa ankle rules in a US Army troops medical clinic in South Korea was studied by Spriger *et al.* [8] who reported a sensitivity and specificity for the rules at 70% and 73% respectively. The positive and negative predictive values were 31.8% and 93.3% respectively. Leisey *et al.* in 2004 observed that correct implementation of the OAR has a definite potential to decrease the use of radiographic resources in deployed military population [9]. Papacostas *et al.* (2001) studied Ottawa ankle rules protocol in Greek athletes and concluded that the Ottawa ankle rules protocol is 100% sensitive [10]. Karpas *et al.* (2002) studied the application of OAR in paediatric emergency department and found that the use of the OAR had reduced the radiography rate by 21% [11].

All prior reported studies were aimed at utilizing these rules for the prediction of frank fractures by plain radiography. In contrast, we have attempted to validate the OAR through bone scintigraphy, the most sensitive diagnostic modality for skeletal trauma. This first reported study of its type compared the OAR findings with x-ray and bone scan results with an aim to validate the sensitivity and specificity of OAR.

Patients and Methods

The study was carried out at Nuclear Medical Center, Armed forces Institute of Pathology, Rawalpindi. The patients were referred from the orthopaedic department of the Combined Military Hospital, Rawalpindi. A total of 60 subjects were studied, which included 10 normal controls (6 males, 4 females) and 50 patients with acute ankle or mid foot injuries (41 males, 9 females) fulfilling the criteria for a positive Ottawa ankle rule. The age of the subjects ranged from 12 to 64 years (mean 29±12 years). Each patient was examined by 3 doctors including a general physician, a surgeon/orthopaedician and a nuclear medicine physician. The study exclusion criteria were more than 30 days since injury, pregnancy, an obvious deformity of ankle or foot, crush injuries, diabetic foot, and children below 12 years of age.

After routine history taking and clinical examination, fresh ankle and foot x-rays (AP and lateral views), were advised. The study procedure was explained to the patient and

Table 1 *Relationship between clinical features, x-ray findings and bone scan in OAR-positive cases*

Sr. no.	Clinical Features (symptoms)	Freq.	% Freq.	X-Ray Findings (frequency)		Bone scan Findings (frequency)	
					Fracture	NAD	A.B.L. (% age of lesion detection)	NAD
1	Pain + Swelling + Inability of wt.bearing	12	24	12 (100%)	-	12 (100%)	-
2	Pain + Swelling.	6	12	-	6	6 (100%)	-
3	Swelling only	2	4	-	2	2 (100%)	-
4	Pain only	25	50	-	25	25 (100%)	-
		5	10	5 No pain, No swelling	5	-	5
Sign:Tenderness (OAR+ve)		50	100%	12	38	45	5
6	Medial malleolus	18	36	3	15	16 (88.8%)	2
7	Lateral malleolus	17	34	4	13	16 (94.1%)	1
8	Navicular	12	24	3	9	10 (83.3%)	2
9	Base of 5th metatarsal	3	6	2	1	3 (100%)	-
Net Result		50	100%	12	38	45	5

NAD: No abnormality detected. OAR: Ottawa ankle rule. Wt: weight. % Freq.: percentage frequency. A.B.L.: Active bone lesion.

informed consent was taken. A 3-phase bone scan was performed on the next working day using dose injected in each case was 16 mCi. The patient was positioned supine under the gamma camera fitted with a low-energy general-purpose collimator and 16 mCi (~600 MBq) of technetium-99m labelled methylene diphosphonate (^{99m}Tc-MDP) was injected intravenously. A dynamic flow study (1st phase) was obtained at 1-sec/frame for 60 seconds. This was followed by a blood pool image at 2 minute (2nd phase), for 1 min. Four delayed static images in the anterior, posterior, right-lateral and left-lateral projections were subsequently at 3 hours postinjection (3rd phase). The delayed spot views were count-based with 300 k-counts per image. The scan were interpreted independently by three nuclear medicine specialists.

Statistical analysis The data was tabulated and the means and standard deviations (S.D.) were calculated for each group and the chi-squared test applied to obtain statistical inference considering p value of <0.05 as significant. Taking the bone scan as the gold-standard, the sensitivity, specificity, PPV and NPV of Ottawa ankle rule were calculated.

Table 2 *Optimisation of the results*

Group	Number	X-Ray Findings		Bone scan Findings	
		Fracture	NAD	A.B.L.	NAD
Patient (OAR +ve)	50	12	38	45	5
Control (OAR -ve)	10	-	10	2	8

NAD: No abnormality detected. A.B.L.: Active bone lesion.

Results

Out of the 50 OAR-positive patients, only 12 cases had a complete fracture detected by x-rays, with the patients complaining of pain, swelling and tenderness and all of them were unable to bear weight on the affected side. Rest of the clinical findings, x-rays and bone scan results are shown in Table 1.

Out of the 50 OAR-positive cases, 45 had positive scans, i.e. 90% of lesions were picked up by bone scan, while only 10% of OAR-positive cases had a normal bone scan.

Figure 1 shows the ability of various diagnostic modalities to pick bone and soft-tissue lesions. In this study, out of 50 OAR-positive cases, x-ray could pick only 24% of the lesions (12 out of 50) and missed 76% of the lesions, whereas in contrast 90% of the lesions (45 out of 50) were picked up by bone scintigraphy which also included two soft-tissue injuries, that were picked up by Ottawa ankle rule and were confirmed by the bone scan.

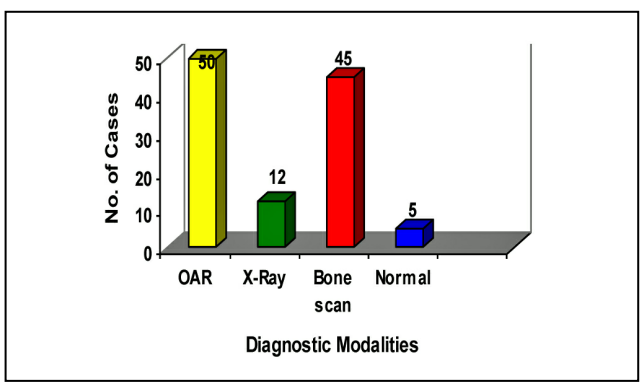

Figure 1 *Comparison between clinical evaluation criteria (OAR), x-ray and bone scintigraphy*

For our control group we selected 10 OAR-negative individuals as control subjects, 7 out of 10 of whom were army personnel.

Optimisation of results was performed to determine the best technique for the diagnosis of acute ankle/foot injuries or arrive at the best possible combination (see Table 2).

Chi-squared test applied to obtain statistical inference considering p value of <0.05 as significant considered the null hypothesis, i.e. x-ray and bone scan are equally good for validation of Ottawa ankle rule. With the degree of freedom 1 and p value as <0.05, we found that our calculated value (22.7) was much higher than tabulated value (3.84), thereby rejecting the null hypothesis and allowing us to conclude that the bone scan was significantly superior to x-ray for validation of Ottawa ankle rule.

Since OAR is a set of clinical criteria based on subjective finding, it cannot form a criterion for evidence based medicine. For its validation we selected the most sensitive imaging modality, i.e. bone scan, as the gold standard and determined the sensitivity of OAR at 95%, specificity at 61.5%, positive predictive value (PPV) at 90%, and negative predictive value (NPV) at 80%.

Discussion

Ankle and foot injuries are very common in clinical practice, constituting a major proportion of cases in emergency medicine. X-Ray is considered to be the most important method of evaluation of bone lesions, but most of the times, it just increases the work

load on x-ray department [2]. The Ottawa ankle rule (OAR) was introduced in 1992 to cope with this problem. The OAR incorporates guidelines for ordering x-rays in acute ankle and mid-foot injuries [5]. Appropriate utilization of OAR can reduce the number of radiographic requests by 22.4% [12].

These days evidence-based medicine is stressed by the medical professionals. The OAR, being only a set of clinical criteria, could be called as subjective only [15]. This is one of the reasons that children below 12 years of age were not included in the study, as OAR is a clinical judgement, which is difficult to appreciate in children correctly and there is always a chance of over estimation. Though Dayan *et al.* in 2004, observed malleolar zone and mid-foot zone fractures in children and found the rule to be reasonably sensitive [14].

In this particular scenario, it was essential, that there should be an evidence-based study for validating these rules, and for this purpose we chose the highly sensitive imaging technique of the radionuclide bone scan. Thus to fulfil the criteria of evidence-based medicine for the validation of OAR, we utilized the radionuclide bone scan, which has proven high sensitivity and a reasonably high specificity [16,17] and found that the sensitivity of the Ottawa ankle rule came out to be 95%, positive predictive value and negative predictive value were 90% and 80% respectively.

We performed x-rays and bone scans on all of the 50 OAR-positive patients and observed that that out of 50 cases only 12 (24%) had fractures on x-rays whilst 45 (90%) had positive bone scans and out of these 45, 43 had active bone lesions and 2 had soft-tissue injuries.

Our control group included 10 volunteers, all OAR negative. But out of these 10, 7 were military personnel, who routinely undertake physically stressful activities [13] with the result that 2 (20%) subject (Table 2), had a false-positive scan. We presume that if we could take a larger control group and all were selected from the general public rather than a fixed occupational group, the results could be even better.

Our study is an analytical study in which we validated the OAR using the radionuclide bone scan. In the study, out of the 50 OAR-positive cases, only 12 (24%) came out to be frank fractures picked up by the plain radiographs (Table 1). The rest of the 38 cases were sprains, confirming the fact that a sprain is much more common problem that can be easily missed by an x-ray, but can be picked up by clinical assessment criteria i.e. OAR.

In this study, we could detect a wide range of lesions with fixed assessment criteria used. Figure 2 shows an intensely hot lesion at the base of the 5th metatarsal in the left foot, which was due to a fracture picked up by plain radiography. But on the bone scan, it was observed that adjacent talus also had an active bone lesion, which was not detected by plain x-ray, indicating the usefulness of bone scan in the diagnosis of such cases.

Another important finding was presence of soft -tissue lesions (Figure 4) indicating that OAR criteria are so valid and significant and that they can even pick up soft-tissue injuries, which definitely needs early identification and management in order to avoid long-term complications [18].

In our control group, we have seen that the false-positive rate was rather high (20%) representing 2 out of 10 cases. This could be due to high bone scan sensitivity [19], that can even pick up mild, localized inflammatory lesions, associated with routine stress (as in our case of military personnel) who were otherwise asymptomatic. This results in high false-positive values, reducing the specificity of the rule, which in our study came out to be at 61.5%. We think that if we have to apply OAR randomly on the general public, the specificity will be definitely higher due to lower false-positive rate.

It was observed that, in almost all the cases there was increased perfusion and blood pool

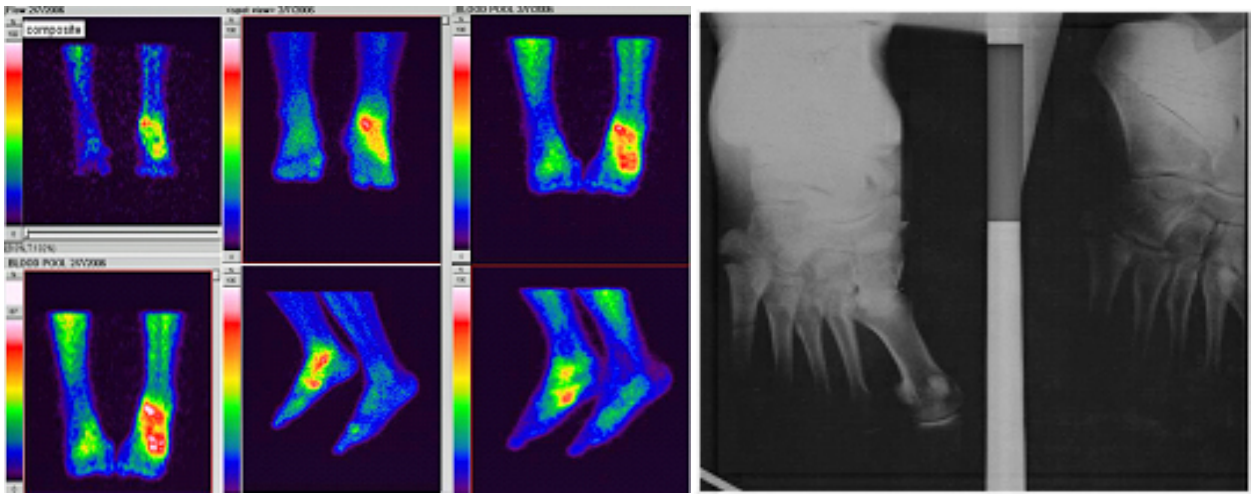

Figure 2 *A 52-year-old male (case 1) with a history of trauma to the left foot with tenderness at base of the left 5th metatarsal and navicular bones. Bone scan (left) shows active bone lesions at the base of left 5th metatarsal and the adjacent talus, with the x-ray (right) showing fracture at the base of the left 5th metatarsal*

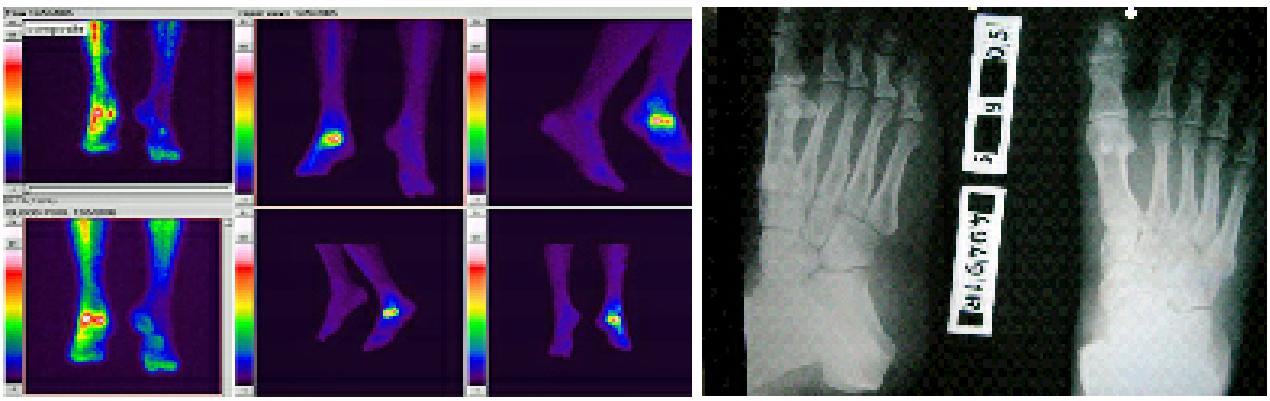

Figure 3 *A 34-year-old female (case 2) with history of trauma to the right foot with tenderness over the right navicular bone. Bone scan (left) shows an active bone lesion in the right talus, with a normal x-ray (right)*

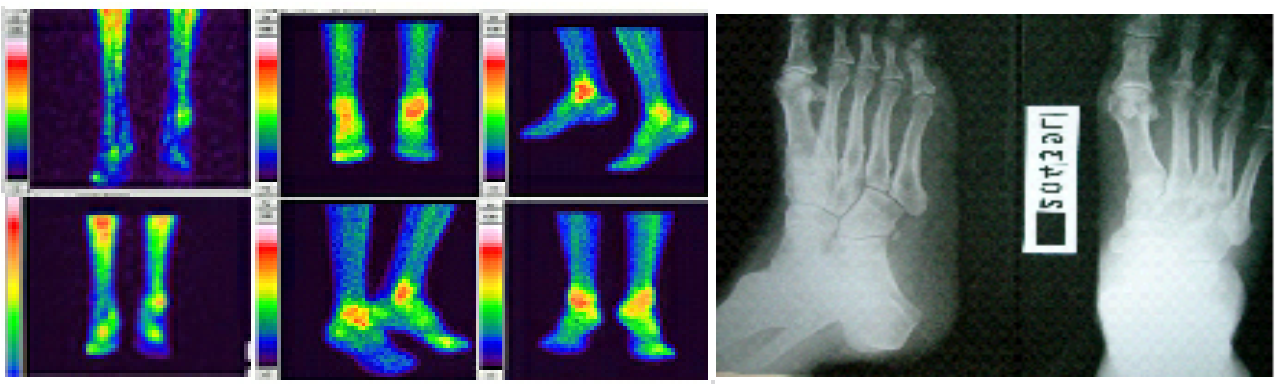

Figure 4 *A 41-year-old male (case 3) with history of trauma to the left foot with tenderness below and behind the lateral malleolus. Bone scan (left) shows increased uptake in lateral malleolus on the perfusion and blood pool images with normal delayed views consistent with soft-tissue injury; the x-ray is normal (right)*

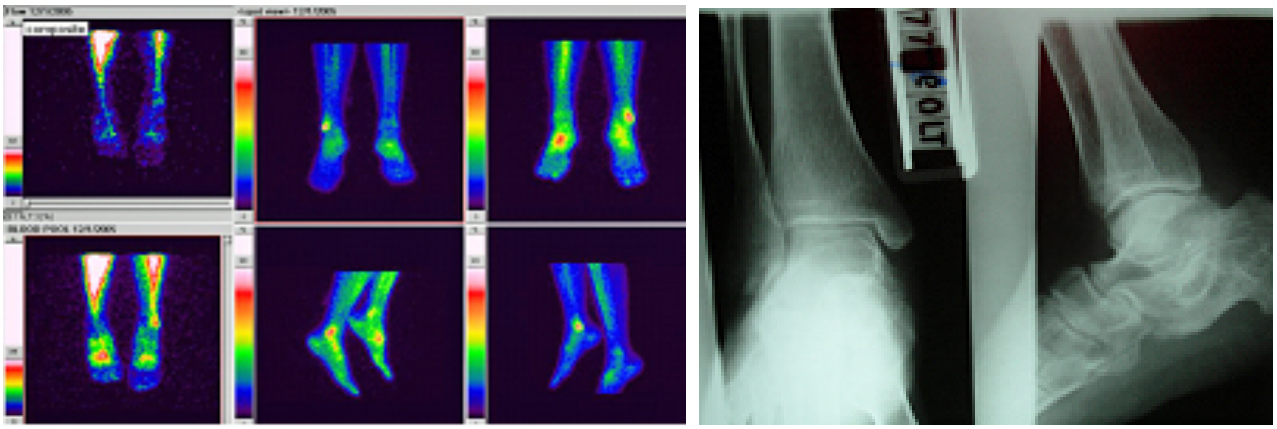

Figure 5 *A 16-year-old female (case 4) with history of trauma to the left foot with tenderness over the lateral malleolus. Bone scan (left) shows an active bone lesion in the left lateral malleolus; the preliminary x-ray was reported to be normal but a repeat x-ray confirmed the lesion*

on the contralateral side and delayed static views also showed slightly raised tracer uptake. We know that whenever there is increased pressure or weight bearing at any site, this initiates a remodeling process in the bone, causing increased radiotracer uptake [20], but such uptake is physiological.

One may query the importance of a set of clinical criteria. The answer to that question is cost, time and convenience. A simple but thorough clinical examination involves minimum time and cost equivalent to a single visit to a physician and with no radiation exposure. We may wonder that on a simple clinical examination one may somehow miss some important findings. However, we have seen that by simply utilizing the OAR criteria, we can pick as minute bone lesions, stress fractures, and even soft-tissue injuries, which can only be detected by bone scintigraphy. These stress-related injuries, if missed, can transform into more serious lesions such as conversion of stress fractures into frank fractures, which can be avoided by utilizing the OAR [21].

Another important aspect is the cost effectiveness of the implementation of the rule. We have made a rough estimate of cost for unnecessary x-rays in this study, and it was observed that at least 20-30% of the total cost and a lot of precious time can be saved, if the OAR is properly utilized.

One thing that is worth mentioning is that, we are not recommending bone scan for every patient with a positive OAR, rather we are suggesting that there is no need of any diagnostic test after a positive OAR in a patient with acute ankle injury. We can directly switch on to the management, which in most of the cases is conservative and involves immobilization, analgesics and anti inflammatory drugs for 3-6 weeks [22]. But if for some reason confirmation of lesion is essential, for example for some documentation like job requirements, insurance purposes, etc., one should go for bone scintigraphy as it will most accurately pick up all types of bone lesions.

We therefore strongly recommend that with a OAR is positive, a person should be considered as an injured person and he/she should receive optimal treatment. But if the physician himself is not very confident in declaring the patient as OAR-positive, in mild cases, only 1-2 weeks immobilization with mild analgesics will be enough and neither x-ray nor bone scanning is recommended [19].

The discussion above may give a false impression that perhaps we totally negate the

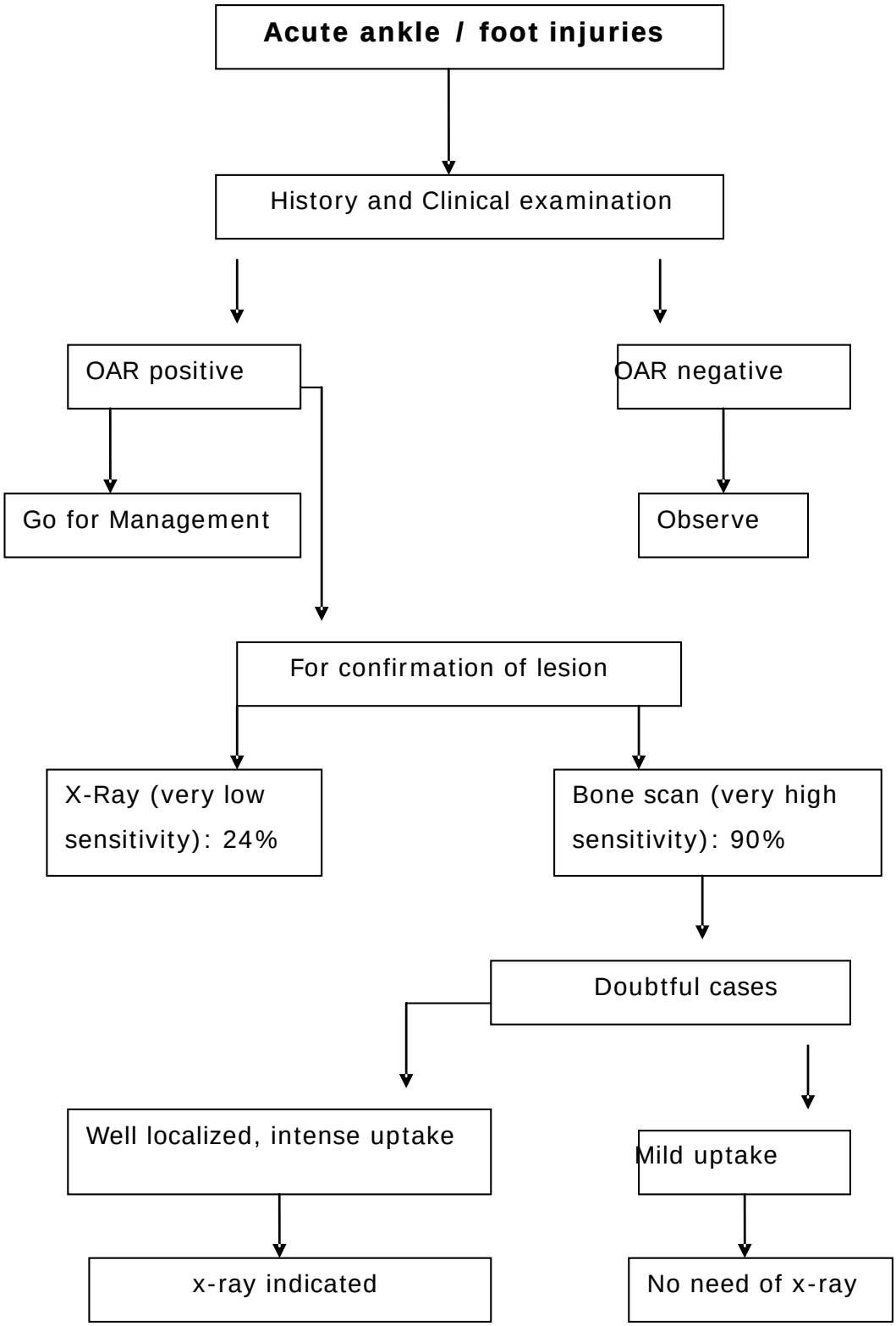

Figure 6 *An algorithm for assessment of the patients with acute ankle/foot injuries*

importance of plain radiograph. This is not the case as x-rays are definitely indicated in some cases where we need a higher specificity rather than high sensitivity. So whenever an orthopaedician is suspecting a frank fracture that may need some intervention like open reduction or internal fixation, x-ray is strongly indicated.

Now the question arises when one should go for x-ray after bone scintigraphy? The answer is, when the lesion is very hot and well localized in all the 3 phases of 3-phase bone scan. This is an indication for plain radiograph after bone scintigraphy but the simple visual impression will not be enough. Semi-quantitative analysis should decide the cutoff point in such cases. A bone scan will then compliment the x-rays. Another possibility could not be excluded was that that fractures were present and radiologist was unable to see the fractures. Even in our study, we had 2 cases, one of which is shown in Figure 5, where the patient had a twisting eversion injury of left foot and the initial x-ray was reported as normal whereas bone scan detected an intense, well-localized lesion at left lateral malleolus. Repeat x-ray was then performed, of the specific site with a specific zoom and it was then reported to have a hairline fracture at the level of the lateral malleolus.

We propose an algorithm for the assessment of the patients with acute ankle/foot injuries (Figure 6) and we expect that if the physicians follow this algorithm for evaluation of patients with acute ankle/foot injuries, there will be a minimum chance of missing a significant lesion and the quality of medical care will definitely improve.

We recommend extensive utilisation of the Ottawa ankle rule in surgical emergency departments, to detect all sorts of bone lesions in acute ankle/foot injuries. The emergency staff should be properly trained to learn and implement OAR in all the cases with acute ankle and foot injuries.

Conclusion

Evidence supports the Ottawa ankle rule as an accurate and very effective instrument for detection of the ankle and mid foot injuries. The OAR has a sensitivity of 95% which is comparable to bone scintigraphy and reasonably high specificity at 61.5%. Therefore in patients with acute ankle/foot injuries, with positive OAR, even with a negative x-ray, the injuries should be taken seriously. However, in difficult cases, bone scan can play a complementary role to plain radiographs. The widespread application of OAR can save both time and money without compromising quality of medical care.

References

1. Bachmann LM, Kolb E, Koller MT, et al. The Ottawa ankle rules have a high sensitivity for excluding fractures of the ankle and midfoot in acute ankle sprain. Evid Based Med. 2003;8:185.
2. McCann B. Prospective survey to verify the Ottawa ankle rules. J Accid Emerg Med. 2000 Jan;17(1):75-76.
3. Dowling S et al. Accuracy of Ottawa Ankle Rules to exclude fractures of the ankle and midfoot in children: a meta-analysis. Acad Emerg Med. 2009 Apr;16(4):277-287.
4. Murray SR, Reeder MT, Udermann BE, Pettitt RW. High-risk stress fractures. pathogenesis, evaluation, and treatment. Compr Ther. 2006;32(1):20-25.
5. Stiell IG, Greenberg GH, McKnight RD, Nair RC, McDowell I, Worthington IR. A study to develop clinical decision rules for the use of radiography in acute ankle injuries. Ann Emerg Med. 1992;21:384-90.
6. Stiell IG, McKnight RD, Greenberg GH, et al. Implementation of the Ottawa Ankle Rules. JAMA. 1994;271:827-32.
7. Pigman EC, Klug RK, Sanford S, et al. Evaluation of the Ottawa clinical decision rules for the use of radiography in acute ankle and midfoot injuries in the emergency department: An independent site assessment. Ann Emerg Med. 1994;24:41-45.

8. Springer et al. A Prospective Study of Modified Ottawa Ankle Rules in a Military Population: Interobserver Agreement between Physical Therapists and Orthopedic Surgeons. J Am Med Assoc. 2000;28:864-868.

9. Leisey, John K, et al. Prospective Validation of Ottawa Ankle Rule in Deployed Military Population.. Military Med. 2004;34:236-239.

10. Papacostas et al. Validation of Ottawa ankle rules protocol in Greek athletes: study in the emergency departments of a district general hospital and a sports injuries clinic; Br J Sports Med 2001;35:445-447.

11. Karpas et al. Utilization of the Ottawa Ankle Rules by Nurses in a Pediatric Emergency Department; Acad Emerg Med. 2002;9:130-133.

12. Auleley G-R, Ravaud P, Girauduaeu B, et al. Implimentation of the Ottawa ankle rule in France: a multicenter randomized controlled trial. J Am Med Assoc. 1997;277: 1935-1939.

13. Rosen A, Sinopoli M et al. Impact of Ottawa ankle rules in a U.S. Army troop medical clinic in South Korea. Military Med. 1999;164:793-794.

14. Dayan et al. Derivation of Clinical Prediction Rules to Identify Children with Fractures after Twisting Injuries of the Ankle Acad Emerg Med. 2004;11:736-743.

15. Michelle J, Michael R. S, John D. K. Clinical Usefulness of the Ottawa Ankle Rules for Detecting Fractures of the Ankle and Mid foot. J Athl Tr. 2010;45(5):480-482.

16. Cross well S, Leaman A, Phung W. Minimising negative ankle and foot X-rays in the Emergency Department -- are the Ottawa ankle rules good enough? Injury. 2014;45(12):2002-2004.

17. Freeman LM, Blaufox MD. Editors; Orthopedic nuclear medicine (part 1), Semin Nucl Med. 1997;27:307-389.

18. Mcgriff-Lee, Management of Acute Soft Tissue Injuries; J Pharm Pr. 2003;16:51-58.

19. Lowrence EH. Orthopedic Imaging in Trauma and Sports Medicine. In: Lowrence E. H, Manuel L. B, eds. Skeletal Nuclear Medicine, 2nd edition.1990;225-258.

20. MatiYong-W Bahk, Yong-An Chung, Use of Gamma Correction Pinhole Bone Scans in Trauma. NuclMedMolImaging.2012;46(1)10-19.

21. Thrall Bachmann et al. Accuracy of Ottawa Ankle rules to exclude fractures of the ankle and mid foot: BMJ, Feb. 2003:326-417.

22. Jeffery D. Tiemstra. Update on Acute Ankle Sprains. Am Fam Physician. 2012;12: 1170-1176.